Neuro-Bio-ICT

Expert Consultation Workshop
9 & 10 November 2009

Report

Future and Emerging Technologies

Proactive

European Commission
Information Society and Media

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1. Introduction

Research in Information and Communication Technology (ICT) inspired by Neuroscience or, more generally, by Biology – as funded by the Future and Emerging Technologies (FET) Programme – is entering its second decade. Driven by highly interdisciplinary research work, with neuroscientists and biologists on one side, and engineers, physicists and computer scientists, on the other, Neuro-Bio-ICT is striving for innovative approaches to information processing beyond current computer architectures, by looking at the amazing processing capabilities in nature, above all by the human brain or the nervous systems found in other species. Major progress in both neuroscience and engineering in recent years has lead to promising results, but fully deciphering a brain's ability and using it for engineering applications and electronic hardware implementation remains a long-term and high-risk goal. In order to identify the most immediate challenges in the field, as well as helping to guide research strategies for remaining calls within FP7, an expert consultation workshop took place on Nov. 9-10, 2009. This report summarizes the main results and visions emanating from that workshop.

2. The workshop

A number of European experts from diverse fields, including biology, neuroscience, electronic engineering, physics, computer science, and artificial intelligence (see Annex I), gathered for two days to discuss the major challenges in the field of Neuro-Bio-ICT. Initially, participants were asked to summarize their personal views on major research topics that should be included in FET calls 2011-2012, as well as comment on the relevance of the Neuro-IT Roadmap[1] today. Furthermore, participants were asked about proper funding instruments, collaboration with institutions outside the EU, and the capabilities of the European research body with respect to the research challenges. (See "Terms of Reference" in Annex II). Short position papers (including ones from experts that were not able to attend), as well as brief presentations at the workshop start, formed the basis for discussion and consensus finding. (Links to written contributions can be found in Annex III).

To form a crystallization point for the consultation, the Commission suggested the discussions could begin around the following, nonexclusive and overlapping areas:

- Neural engineering, covering topics such as
    - Multi-channel, multi-modal (e.g. chemical and electrical) neuronal interfaces
    - Nano-bio convergence (e.g. nanotube electrodes)
    - Neural coding
    - Bio-hybrid systems

- Sensing, perception and acting, covering topics such as
    - Bio-inspired multi-sensing
    - Multi-sensory fusion
    - Sensing-action integration
    - Object recognition and categorization

[1] www.neuro-it.net

- Bio-computing: devices/systems mimicking or inspired by neural systems, e.g.
    - ICT inspired by a deeper understanding of cognitive functions of the brain
    - Computational neuroscience models for ICT

Consequently, two groups were formed to discuss the first two areas in parallel, while the third area was discussed in the plenum.

The brainstorming and discussion part of the workshop benefitted greatly from the diverse backgrounds of the participants with sometimes opposing views on some research strategies. A large consensus, however, could be found on the view that

- the main research agendas, as defined in the Neuro-IT Roadmap, are still fully valid and will keep guiding research in coming years;
- work topics from previous FET calls (such as “Neuroinformatics for Living Artefacts”, “Lifelike Perception Systems”, “Bio inspired intelligent information systems”, “Bio ICT convergence”, and the current calls “Human computer confluence” or “Brain inspired ICT”) are also still relevant for research needed in the field, and progress made thus far does not make these topics obsolete;
- nevertheless, new foci for calls in 2011-2012 can be identified, which should be understood as enhancing rather than constraining the research work toward Neuro-Bio-ICT;
- and Europe definitely has the critical mass of researchers in the right kind of fields to carry out such a program.

A number of important issues were raised and discussed, including the following:

- Despite progress in neuroscience, as well as computational neuroscience, we are still far away from understanding function in neural assemblies and circuits, and how the brain represents or “encodes” information. Much more work is needed – from developing improved stable multi-cell recordings to enhanced theories and new modelling paradigms to large scale implementations – in order to get closer to a true understanding of the brain and to progress towards novel neural-based computing architectures.
- There is an increasing need for multi-scale approaches, with respect to measuring (from single cell to EEG), modelling neural dynamics at the corresponding scales, as well as learning. Some functions are understood on each level, but in order to make advances in understanding their interdependence and the coherent control structure of the brain, work needs to focus on furthering our understanding on all levels, as well as of how the signals and coding relate across levels. It was noted that the next call in “Brain-inspired ICT” will already address this important aspect.
- When talking about “the brain” one should not be confined to human, or even mammalian, brains, but any nervous system found in nature, the understanding of which can help further ICT research, is of equal interest. Animal research, in particular neuroethology and comparative physiology, is of prime importance for the advancement of Neuro-Bio-ICT.
- In order to learn about the way the brain represents and processes information, artificially controlled stimulation of cells or neural circuits can play an equally important role, both as a probe into the neural dynamic representations and as an agent to induce plastic changes in the functional architecture, for instance inducing new representations associated with a specific behaviour. In addition, improvements of and novel approaches to network stimulation are needed for closed-loop systems in brain-machine interfaces, and for progress in neuro-rehabilitation.

- The study of neural computation can benefit by being complemented or inspired by approaches from machine learning or statistics – such as Bayesian networks, belief systems or reinforcement learning – that provide possible principles or frameworks for describing the massive data acquired in neuroscience, or offer pathways for more comprehensive views on higher-level processes in the brain.
- Much more than currently available can be expected from applying dynamical and complex systems theory to the modelling of neural processing. As an example, it has been suggested to view the brain as working on the border of different types of criticality. The identification of the underlying mechanisms and their properties, as well as the exploitation of this structure could greatly enhance our progress toward neuro-inspired processing.
- The lack of understanding how representations are grounded in (multi-)sensory stimuli is still a major bottleneck in progress on neurocomputers, especially due to the need of proper multi-sensor fusion strategies.
- Hardware and VLSI technologies for bio-computing are quite advanced, including first approaches to 3D VLSI systems. However, further progress is needed for understanding how to design and program artificial neural systems with adaptive and learning capabilities. Major technical challenges concern connectivity, plasticity, energy consumption and heat dissipation.
- There is still room for improvement in how the different scientific communities can talk to each other, make accessible their data and their conceptual approaches to each other, and find a common vocabulary for communication. As an example, "coding" can be understood quite differently by biologists and computer scientists. On a more general level, there is still a need for neuroscientists and engineers for better aligning their research strategies, what each expects as a research outcome and how both sides can optimally benefit from each other.

Further bottlenecks impeding on research progress were also identified, such as the following:

- The reasons for seeking bio-inspiration for machine implementations are not always clearly defined: models need to go beyond simple mimicry of biological phenomena and should rather seek to extract principles that might be used for novel (not necessarily biological wetware based) implementations leading to more effective machine function; similarly application of physical, mathematical or engineering principles may find applications in reverse engineering neural function and may produce novel approaches to exploring and understanding brain function.
- The upcoming revision of the EU directive on animal research puts several research strands at risk. In particular, basic research in non-human primates will almost certainly be dead if the directive comes into effect as currently drafted. Better definition of the ultimate research goals and reaffirmation of the need for animal experiments, as well as communication to the public may help prevent this.
- There is still a lack in proper education in the field with respect to training researchers with interdisciplinary skills that are badly needed (e.g. summer schools organized in the Neuro-IT framework).
- Current funding instruments (IP, STREP, NoE) are seen as insufficient and need to be complemented by additional instruments allowing longer time scales, as well as more continuity between projects and potential follow-up research. Currently, in FET the attempt to (re-)use successful project results in a new project is seen by some as almost an exclusion criterion in the constant drive toward new high-risk ideas.

3. The outcome: Research challenges and topics for 2011-2012

3.1. Motivation

Brains are remarkable computing devices which clearly outperform conventional architectures in real-world tasks. Computational neuroscience has made tremendous progress in uncovering the key principles by which neural systems carry out computation, and ICT has advanced to a point where it is possible to integrate almost as many transistors in a VLSI system as neurons in a brain. Yet, we are still unable to develop artificial neural systems with basic computing abilities able to parallel even simple insect brains.

Understanding the computational principles used by the brain, how they are exploited for processing, and how to implement them in hardware real-time behaving systems is crucial for developing radically novel computing paradigms and constructing a new generation of ICTs that combine the strengths of VLSI technology with the performance of brains.

In recent years, experimental and theoretical neurosciences have been subject to a spectacular expansion, in part because of a series of new techniques of measurement, and the associated theoretical frameworks that were developed. To mention only a few, optical imaging techniques now enable the experimentalists to monitor simultaneously large populations of neurons, and in some cases, the animal may express (through genetic modifications) specific markers of activity that will be measured by specifically designed equipment. Theoretical and computational approaches are designed in parallel to these experiments, and new frameworks need to be conceived every time new types of recording techniques appear. New theoretical concepts are therefore often correlated with the availability of new experimental techniques.

One of the most exciting applications of the neurosciences is towards the design of new generations of electronic circuits and "neural computers". In this case, it is necessary to combine several disciplines, such as biological experimentation, theoretical/computational neuroscience and engineering. The biological experiments characterize the brain activity, computational neuroscience formalizes computing principles in models, and engineering implements these models on specific hardware circuits. A series of European-funded projects (FET Proactive and Open), such as FACETS, DAISY or SECO, among others, follow this approach presently .

Research funded under the FET programme for the past 10 years has been at the forefront of activities in the field of Neuro-Bio-IT worldwide and has lead to European leadership in many of its sub-areas. It has also helped establish long-standing interdisciplinary collaborations und a lively and competitive scientific community. Thus, it is more than timely to continue and strengthen this research path by both continuing on its main research themes – as laid out, among others, in the Neuro-IT Roadmap – and re-focusing on some of the most urgent challenges in the field.

3.2. Grand Challenges

For research to be funded in 2011-2012, the following main challenges need to be addressed:

Challenge 1:
To learn more about the relationship between structure, dynamics and function in neuronal circuits and assemblies, and how information is represented or “coded” in the patterns of neuronal activation.

Challenge 2:
To develop deeper and more comprehensive theories of neural processing, in particular those based on paradigms from dynamic and complex systems.

Challenge 3:
To close the still-existing gap between neuroscience and engineering by further motivating interdisciplinary work that ties data with theories, models and implementations.

To address these challenges, work and expertise is needed from several areas:

- Neuroscience, together with Neural Engineering, to gather and make available data from the biological substrates, in order to feed theories and models and to inspire hardware implementations. Neural Engineering is further needed to provide improved stimulation techniques in order to enable closed-loop systems and brain-machine interfaces for ICT applications.
- Theory and modelling to provide new paradigms of simplified neurally inspired computation or processing, owing to the strongly dynamical nature of biological processing, and to help build an overall architecture of brain-like behaviour control.
- Hardware and biological engineering to enable proper implementations of novel computing and processing paradigms in substrates more suitable than conventional computers, including hybrid engineering combining hardware with “bioware”.

A proper research project does not need to be strong in all these areas, as long as it addresses at least one of the grand challenges and focuses on primarily benefitting ICT in its potential outcomes and impacts. Research can further benefit from additional disciplines such as comparative neuroethology, cognitive science or robotics.

3.3. Research Topics

The following is a list of what is considered as major research topics needed to address the three challenges. While each has a certain focus (e.g. more neural engineering or more bio-computing), a research project tackling one or more of them should nevertheless remain highly inter-disciplinary and keep oriented toward the overall goals of Neuro-Bio-ICT.

Topic 1:
Long-term stable recordings of neural signals and multi-scale distributed recordings in space and time for a deeper understanding of neural processing

While the amount of data available in neuroscience is increasing rapidly, there is still a lack of proper tools to collect stable sets of dynamic data that would help to link structure with function in neuronal circuits with the resolution required to optimally understand this link. Reliable, stable, and long-term recording is especially needed to monitor and understand the processes of reorganization of the brain's functional connectivity dictated by a changing sensory environment and behavioural demand.

Thus coordinated efforts and systematic approaches are needed for developing radically new neural recording designs that are optimally matched to the biophysical properties of the brain tissue. The goal is to integrate information obtained from multiple recording technologies done simultaneously over multiple areas, over long periods of time in behaving subjects, and to understand which kind of signal is conveying which information. Among others, this requires the development of multi-level data acquisition and measurement approaches that determine the representation of the neural recordings at multiple time-scales. Work needed also includes research on novel non-invasive techniques to image neuronal activity with high time resolution, as well as new approaches to chemical sensing that enable long term measurements and target neuroactive compounds not yet monitored in vivo.

Topic 2:
Dynamically reconfigurable neural interfaces

Neural interfaces represent a crucial instrument for making progress in Neuro-Bio-ICT. Progress and breakthroughs in research involving neural interfaces can be achieved only by pursuing a fully integrated interdisciplinary approach that covers fundamental research in neuroscience, neural engineering (material science, low-power electronics for brain machine interfaces, *etc.*) as well as the *joint* development of computational theories, neuro-computational hardware architectures, and embodied neuro-computational systems able to carry out real-time behaving tasks in real-world, uncontrolled scenarios.

Indeed in many applications, ranging from tools for basic research, to brain machine interfaces and to stimulation for medical use, there is a need for an integrated approach on neural interface research which can lead

- to understanding dynamic representations at multiple time-scales;
- to characterizing in detail localized and distributed stimulation, in both space and time;
- to developing dynamic recording systems (*e.g.* with reconfigurable recording probes, depending in change on stimulation intensity, reference, electrode site, *etc.*) which dynamically adapt the basic stimulation characteristics as a function of the basic characteristics of the measurements made;

- to developing recording and stimulating systems which can implement dynamic (closed-loop) functional adaptation, depending on the outcome of computations on the measured data (*e.g.* which interpret a planned action); for developing local low-power on-chip neural data analysis and interpretation circuits;
- to developing neuromorphic microelectronic event-driven systems that can learn to interpret the neural data measured and act as an equal partner in a biological information processing chain;
- and to characterizing in a systematic and conclusive way the detailed biophysics of neural tissue.

Topic 3:
Real-time event- or spike-driven Neuro-Bio-ICT systems

It is clear that the spike-driven nature of the sensory data processed by biological neural circuits imposes important constraints on the computational strategies and computing hardware/wetware used by brains, which are fundamentally different from the static frame-based machine vision and machine learning approaches used up to now. Research challenges on brain-inspired real-time event-driven computational systems will lead to a better understanding on the computational principles used by nervous systems, and to the development of artificial (neural) systems able to process in real-time streams of real-world sensory signals (e.g. measured by event-driven VLSI sensory devices) using radically different data-driven approaches, which can potentially solve currently unsolvable problems dealing with real-world data in natural uncontrolled environments.

The main characteristics that make biological neural systems so robust, adaptive, and performing are undoubtedly related to their learning and development properties. Many theories have been developed to explain and exploit biologically inspired learning properties. But very few can be mapped into efficient hardware implementations and be used in real-time behaving systems, or applied to real-world tasks. This is a challenging research problem, and its outcome will rule out a large number of current hypotheses and identify a set of theories and algorithms that can lead to new efficient ICTs and new insights that can explain how the brain works. Analogous arguments can be applied to development theories and algorithms.

Topic 4:
New dynamical theories of neural representation

The aim is to go beyond current theories and models about coding and representation of perception and action in the brain. Key issues are fusing of information from multiple sensory systems, grounding higher-level processes and semantic knowledge in perception and action, understanding brain dynamics at multiple levels, developing brain-like systems for object recognition, object classification, and extraction of affordances for action. A major challenge that remains to be tackled is how to extract, encode, store and retrieve *structured* information – for example, the relations between elements that confer meaning to a scene, or the morphosyntactic rules that we acquire effortlessly when learning a language.

To achieve the above, research proposals should go beyond purely sensory-driven information processing, emphasizing the tight coupling between sensing and action, prediction of the outcomes (sensory and otherwise) of action, and the active structuring of information processing including the construction of internal representation as the abstraction of outside world. Solidly grounding representations in multi-faceted sensory-motor experiences is a crucial aspect of this endeavour.

A major focus is expected on further exploiting models based on dynamic and complex system theory. For example, there is recent evidence that neurons represent different information at different times during the performance of a cognitive task, suggesting that they transiently become members of neural assemblies covering different scales and synchronizing at different frequency bands. The question is what computational approaches, perhaps combining attractor dynamics and synchronization, could account for such observations. Further evidence suggests that neuronal circuits and their dynamical states operate at the edge of several criticalities, which could be crucial for major processing functions. Advanced theory and models are needed that exploit these properties of complex systems and their dynamical states and explain how the brain uses them for representation while remaining rather stable overall, including a systematic investigation of attractor dynamics, other types of dynamic primitives, and their function in both coding and decoding information. One important question is how the analog computation at the level of single neurons and synapses can support, at the population level, the serial, context- and goal-dependent manipulation of sequences of inputs (e.g. in language). This includes an explanation of dynamical pathologies from alterations of the states of the system.

Topic 5:
Toward a modular architecture of brain-like behaviour control

A fruitful way toward understanding the brain is through investigating it as an intricate system of more tractable modules or subsystems. Research should thus focus on identifying a library of neural processing "primitives" (akin to cortical "LEGO blocks"), which can be combined to more complex processing elements, step by step, in a "network of networks" approach. This view also accounts for the fact that neural circuits in different brain areas can have quite different function and dynamics, which need to be understood separately and in combination, for which time is a key element. It is also necessary to consider that the 'whole' is almost certainly not a simple sum of the component parts (or 'modules'). Thus approaches which explore the dynamics of both structure and function and their interdependence at all levels of complexity is encouraged. Another important aspect is the fusion of multiple sensory modalities and their representational capacities into coherent dynamic system of complex object or concept representation. Potential unforeseen emergent properties that can negatively impact on a system's performance should be carefully analysed in this context.

Research should seek to link brain and behaviour (including more cognitive tasks) and provide advances of understanding at the level of function. It is necessary to emphasize the dynamic nature and state-dependence of brain function. Therefore, approaches that treat brain states as a dynamical link between structure and function are encouraged. Brain states are the measurable signatures of an animal's perception of its sensory environment. They can change depending on prior experience and depending on the task an animal aims to accomplish. Brain states are thus crucial to study the highly complex and recurrent integration process of sensory input, memorized experiences, and behaviour. A focus on the role of interactions both within and between different brain areas and on the function of recurrent or top-down connections is a vital prerequisite. Work should aim at reflecting detailed anatomical information about known neuronal circuits and areas, but should also consider emerging observations that it may be misleading to think that neural computing is only spike-based. For instance, possible ephaptic interactions, local field potentials or other graded analogue processes, including glia-neuron interactions, require further exploration.

On the other hand, projects could benefit from the inclusion of comparative approaches to allow insights into fundamental principles and design constraints, ideas from machine learning/information theory, and consideration of mechanisms for selective attention, active filtering, and information reduction. Work can also include purely functional models – e.g.

inspired by computer vision, reinforcement learning, or Bayesian modelling – as long as they contribute to a brain-like overall architecture of behaviour control.

Topic 6:
Beyond existing biocomputers

The aim is for devices that are real-time (or faster), low-power, fault-tolerant, compact, and optimized for brain-like processing. Key issues are event-driven operation, binding of representations across processors, algorithm/dynamics for distributed computation and inference over graphical models (including potentially low-resolution systems), self-assembly, diagnosis and repair, as well as technologies toward very large-scale implementations. By "building to understand", bio-computing architectures are expected to contribute to Neuro-Bio-ICT as a whole and not merely serve as their implementation end.

To achieve the above we need to understand the different styles of handling parallel computation in multiple brain systems, including their ensemble activity, taking into account context-dependency, use of dynamical states, learning, plasticity, homeostasis, and role of non-neural structures in maintenance and support. This work could usefully draw insights from comparative neurobiology (convergent and divergent evolution, e.g. birds vs. mammals) including invertebrates.

Novel bio-computing hardware should go beyond parallel conventional machines making use of special-purpose processors (e.g. analog/digital VLSI), novel technologies (e.g. nano, organic electronics), or biological substrates for information processing, including bio-hybrid systems using in-vitro nervous systems. Key technical issues to solve are connectivity, power consumption, heat dissipation, compactness and potential for miniaturization.

3.4 Impact

The expected impact of Neuro-Bio-ICT on science and engineering is potentially huge and wide-ranging. Neurocomputers built on the principles of information processing in nature can be expected to enable processing applications for which conventional computers are reaching their limits, including complex object and scene recognition, autonomous robot navigation, complex problem solving and inference based on rich sensory stimuli, and beyond. Application areas include medicine (neural prostheses, therapy of neuronal disorders, etc.), robot engineering, real-time autonomous processing, embedded systems, and many more.

The expected impact from addressing the main challenges identified above is a decisive step forward in reaching the ambitious goal of truly natural neurocomputers, by bringing current research to the next level and overcoming the many limits that researchers are still facing today.

4. Relationship to previous research initiatives

In the spirit of the discussions at the workshop – highlighting that research calls from previous FET initiatives still contain valid aims – it is worth looking at whether past or ongoing projects have at least partially addressed the research topics laid out above. The following table provides such an overview. Since many of these contributions are only marginal, altogether the set of research topics still forms a strong guidance for where the main foci should be in 2011-2012.

	FP5			FP6	FP7	
FET initiatives / Research topics	**Neuroinformatics for living artefacts**	**Life-like perception systems**	**Neurons on Si[2]**	**Bio-inspired intelligent information systems**	**Bio-ICT convergence**	**Embodied intelligence**
1: Long-term stable recordings of neural signals and multi-scale distributed recordings in space and time for a deeper understanding of neural processing					BRAINSTORM CYBERRAT RENACHIP	
2: Dynamically reconfigurable neural interfaces		CYBERHAND	INPRO NACHIP NEUMIC		BRAINSTORM	
3: Real-time event- or spike-driven Neuro-Bio-ICT systems		ALAVLSI CAVIAR SPIKEFORCE			CYBERRAT	eMORPH
4: New dynamical theories of neural representation	CEREBELLUM INSIGHT2+	APEREST ROSANA		CILIA		
5: Toward a modular architecture of brain-like behaviour control	BIBA MICROCIRCUITS		NEUROBIT	CILIA	BIOTACT	
6: Beyond existing biocomputers				DAISY FACETS	SECO RENACHIP	

[2] Ad hoc initiative constructed from a group of FET Open projects addressing neurons-on-Si research

5. A potential Flagship Project

The expert group agreed that, given the far-reaching nature of Neuro-Bio-ICT research, the topics identified above, together with the excellent ongoing research in the field, would lend themselves nicely to a definition of a "Flagship Project" as currently solicited by the Commission. A working title could be "Toward a multi-purpose neurocomputer", which could bring together joint multidisciplinary efforts on a larger scale to achieve yet another step toward the field's visions.

Annex I: List of Participants

Workshop participants

Paolo Del Giudice	Italian National Institute of Health, Italy
Alain Destexhe	Centre National de la Recherche Scientifique (CNRS), France
Georg Dorffner	Medical University Vienna, Austria (rapporteur)
Ulrich Egert	University of Freiburg, Germany
Kirsty Grant	Centre National de la Recherche Scientifique (CNRS), France
Giacomo Indiveri	University of Zurich and Swiss Federal Institute of Technology, Switzerland
Bert Kappen	University of Nijmegen, The Netherlands
Jörg Lücke	University of Frankfurt, Germany
Hercules Pereira Neves	Interuniversity Microelectronics Centre (IMEC), Belgium
Tony Prescott	University of Sheffield, UK
Sylvie Renaud	IMS Labs Bordeaux, France
Alessandro Treves	International School for Advanced Studies (SISSA), Italy

Further written contributions

Jacob Engelmann	University of Bonn, Germany
Anders Lansner	KTH Royal Institute of Technology, Sweden
Wim Rutten	University of Twente, The Netherlands

Annex II: Terms of Reference

Consultation for researchers involved with Neuro-ICT research for the 2011-2012 Workprogramme.

9-10 November 2009, Brussels

1. Context

The Future and emerging Technologies (FET) scheme fosters frontier research that opens up new avenues across the full breadth of future information technologies. FET acts as a pathfinder promoting the exploration of radically new ideas and trends for future research and innovation. It also aims at providing sustained support to emerging areas that require fundamental research to be carried out over a long period. The core of FET's mission is to go beyond the conventional boundaries of ICT and venture into uncharted areas, often inspired by and in close collaboration with other scientific disciplines.

In the case of Neuro-ICT, FET looks for radical breakthroughs that exploit fresh synergies, cross-pollination and convergence between the wide range of scientific disciplines involved. Fundamental research in bio-ICT has been systematically pursued in FET since 1999, indicating the sustained and growing importance of this area.

2. Consultation

In preparation for the next 2011–2012 work programme, FET has launched a consultation process involving interactions with researchers in order to identify new challenges and opportunities for the future. This consultation is targeted at converging research between neuroscience and information technology, in particular into the way information is processed and communicated in biological nervous systems. We therefore invite you to present an analysis of grand challenges and what research topics should be included in the FET work programme to tackle them. Discussions can also include the means to implement the research – whether the projects should be big or small, or whether networking or coordination between researchers should be fostered.

The results of the consultation will be published on-line and collected in a report, which it is hoped will outline a broad research theme.

The consultation is organised as a 2 day workshop in Brussels during 9-10 November, 2009.

To start the discussions, participants will be initially involved in 1 of 3 groups addressing:

1. Neural engineering, covering topics such as
    - Multi-channel, multi-modal (e.g. chemical and electrical) neuronal interfaces
    - Nano-bio convergence (e.g. nanotube electrodes)
    - Neural coding
    - Bio-hybrid systems

2. Sensing, perception and action, covering topics such as
    - Bio-inspired multi-sensing
    - Multi-sensory fusion
    - Sensing-action integration
    - Object recognition and categorisation

3. Bio-computing: devices/systems mimicking or inspired by neural systems, e.g.
    - ICT inspired by a deeper understanding of cognitive functions of the brain
    - Computational neuroscience models for ICT

In the beginning of the workshop, participants will be expected to present their suggestions before dividing into smaller groups for more detailed discussions. Participants are therefore requested to prepare a short (5 minute) presentation on the key topics they see for future research in the domain of Bio-ICT. The workshop will conclude with a combined discussion aimed at producing a unified recommendation for a new Proactive Initiative.

Presentations for the meeting should be short (5 minutes maximum) and address the following issues:

- Projects funded as a result of topics in the 2011-2012 Workprogramme will be active between 2013-2016. What are the main scientific and technological challenges for frontier research in understanding the way information is handled in nature (especially neuroscience) that need to be tackled in the next 10-20 years? Do you foresee any bottlenecks that need to be addressed in the medium term? Are the challenges vision-driven and high-risk, embryonic or foundational?

- What research topics should be included in the FET 2011 – 12 Workprogramme to foster research addressing those challenges? How are these different from existing or planned research (e.g. the "Brain-inspired ICT" Proactive Initiative planned for Call 6).

- What is still relevant and what is missing in the Neuro-IT roadmap (see http://www.neuro-it.net/)?

- What funding 'instruments' should FET employ in order to support the research (small projects < 3M€ - 3yrs or large projects ~4-6 M€ - 4-5 yrs)?

- Would international collaboration outside the EU be important for this research and with whom?

- Is there a body of European researchers able to carry out research in this area and interested in submitting proposals?
